EP 1371 5 I (5)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 637 113 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **94304900.7**

(51) Int. Cl.[6]: **H01T 13/39**, H01T 21/02

(22) Date of filing: **04.07.94**

(30) Priority: **26.07.93 JP 184207/93**

(43) Date of publication of application: **01.02.95 Bulletin 95/05**

(84) Designated Contracting States: **DE FR GB IT**

(71) Applicant: **NGK SPARK PLUG CO., LTD**
14-ban, 18-gou
Takatsuji-cho
Mizuho-Ku
Nagoya-shi (JP)

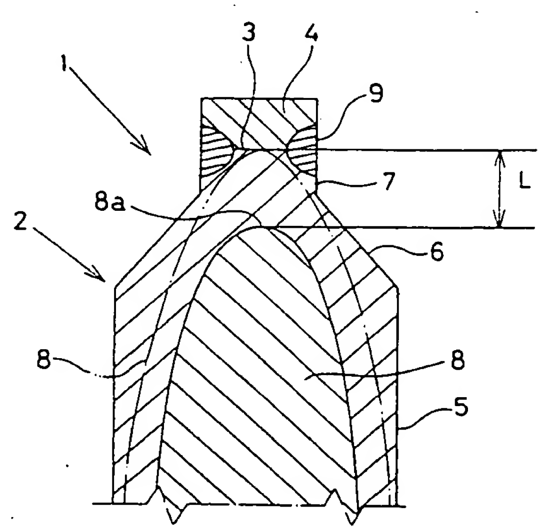
(72) Inventor: **Oshima, Takafumi, c/o NGK Spark Plug Co., Ltd.**
14-ban, 18-gou,
Takatsuji-cho
Mizuho-ku,
Nagoya-shi (JP)

(74) Representative: **Senior, Alan Murray**
J.A. KEMP & CO.,
14 South Square,
Gray's Inn
London WC1R 5LX (GB)

(54) **A spark plug.**

(57) In a spark plug having an electrode metal made from a heat-and erosion-resistant nickel alloy whose front end has a noble metal tip made of iridium or ruthenium, the electrode metal has a thermal conductivity of 30 W/m•K or greater than 30 W/m•K. The electrode metal clads a heat-conductive core, and a front end of the core is in direct contact with the noble metal tip, otherwise the front end of the core is located near the noble metal tip by within a range of 1.5 mm instead of being in direct contact with the noble metal tip.

Fig. 1



EP 0 637 113 A1

This invention relates to a spark plug, in particular to a spark plug for internal combustion engines, wherein the spark plug has an electrode including a metal made from a heat-and erosion-resistant nickel alloy, the front end of which, at which the spark is formed, has a noble metal tip made of iridium or ruthenium.

In a spark plug electrode for an internal combustion engine, one may use a noble metal tip which has been made of iridium or ruthenium, since they are more resistant to spark-erosion than other noble metals such as platinum or the like. This is because iridium and ruthenium have a higher melting point (2447 °C, 2310 °C respectively) than that of platinum by 600-700 °C.

However, iridium and ruthenium are particularly vulnerable to oxidation-based evaporation at high temperatures and thus are more quickly corroded when the temperature exceeds a critical point. That is to say, when made of iridium or ruthenium wear of the noble metal tip is accelerated at this critical temperature.

In order to avoid the rapid wear of the noble metal tip, Japanese Patent Application No. 4-350 discloses a centre electrode 100 for a spark plug, as shown in Fig. 6. In the centre electrode 100, a recess 102 is provided on a front end of an electrode metal 101, and a noble metal tip 103 is fixedly placed in the recess 102. The electrode metal 101 clads a heat-conductive core 104 whose front end 104a is located near a front end 103a of the noble metal tip 103. The heat-conductive core 104 works to draw a considerable amount of heat from the noble metal tip 103 so as to keep the temperature of the tip 103 from rising excessively.

In this instance, the electrode 101 is made of Inconel 600 so as to resist satisfactorily the thermal stress caused by a difference in the thermal expansion between the noble metal tip 103 and the front end of an electrode metal 101. Inconel 600 has a good physical strength at high temperature, but not a sufficient thermal conductivity to draw the heat from the noble metal tip 103.

According to the present invention, there is provided a spark plug having an electrode including an electrode metal of a heat-and erosion-resistant nickel alloy, a front end of the electrode having a noble metal tip made or iridium or ruthenium and the electrode metal having a thermal conductivity of about 30 W/m.K or greater.

Preferably, the electrode metal clads a heat-conductive core, and a front end of the core is in direct contact with the noble metal tip. Alternatively, the front end of the core can be located near the noble metal tip within a range of 1.5mm therefrom.

Advantageously, the noble metal tip is laser welded to the front end of the electrode metal by forming a solidified alloy layer between the noble metal tip and the electrode metal all through their circumferential length.

A spark plug of the present invention may be capable of maintaining the temperature of a noble metal tip relatively low so as to significantly reduce the wear to which noble metal tip is subjected.

With occurrences of spark discharges between electrodes and temperature rise in a combustion chamber, the noble metal tip is exposed to a high temperature environment. In this instance, the electrode metal draws a considerable amount of heat from the noble metal tip due to the reason that the electrode metal has a good thermal conductivity of 30 W/m.K or greater than 30 W/m.K. This avoids an abnormal temperature rise of the noble metal tip to prevent the oxidation-based evaporation of iridium or ruthenium so as to significantly reduce the wear to which the noble metal tip is subjected.

With the front end of the core located near the noble metal tip within the range of 1.5 mm, the heat-drawing effect is facilitated from the noble metal tip to maintain the temperature of the tip sufficiently low so as to minimize the wear to which the noble metal tip is subjected.

With the noble metal tip laser welded to the front end of the electrode metal by forming a solidified alloy layer between the noble metal tip and the electrode metal all through their circumferential length, it is possible to attain a sufficient physical strength of the solidified alloy layer between the noble metal tip and the electrode metal without using Inconel 600.

In order that the invention may be better understood, the following description is given, only by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a longitudinal cross sectional view of a lower portion of a center electrode of a spark plug;
Figs. 2a ~ 2c are sequential views showing how the center electrode is manufactured;
Fig. 3 is a graph showing a relationship between a spark gap (mm) and specimens (A ~ H) employed to an electrode metal;
Fig. 4 is a graph showing a relationship between a spark gap (mm) and thermal conductivity (W/m•K) of the electrode metal;
Fig. 5 is a graph showing a relationship between a spark gap (mm) and a distance (L mm) measured from a front end of the hete-conductive core to the noble metal tip; and
Fig. 6 is a longitudinal cross sectional view of a lower portion of a prior art center electrode.

Referring to Fig. 1 which shows a lower portion of a center electrode 1 of a spark plug the center electrode 1 has a heat-and erosion-resistant electrode metal 2 made of nickel. To a front end 3 of the electrode metal 2, a noble metal tip 4 is secured which is made of iridium or rethenium to provided it with spark-erosion resistant property.

Upon analyzing laser flash method, the electrode metal 2 has a thermal conductivity of 30 W/m•K or greater than 30 W/m•K. Materials employed to the electrode metal 2 are described in detail hereinafter. The electrode metal 2 further has a barrel portion 5 and a cone portion 6 extended from the barrel portion 5 to a diameter-reduced neck 7. The diameter-reduced neck 7 measures 0.85 mm in diameter, and continuously leading to the front end 3 of the electrode metal 2.

In the electrode metal 2, a heat-conductive core 8 is concentrically embedded which is made of copper or copper alloy. A front end 8a of the core 8 is located near the noble metal tip 4 within a range of 1.5 mm. Otherwise, the front end 8a of the core 8 is in direct contact with the noble metal tip 4 as shown at phantom line in Fig. 1.

The noble metal tip 4 is made from an iridium-or ruthenium-based alloy containing oxides of rare earth metals. The noble metal tip 4 is laser welded to the front end 3 of the electrode metal 2 by forming a solidified alloy layer 9 between the noble metal tip 4 and the front end 3 of the electrode metal 2 all through their circumferential length. The solidified alloy layer 9 makes it possible to physically strongly bond the noble metal tip 4 to the front end 3 of the electrode metal 2.

A method of bonding the noble metal tip 4 to the front end 3 of the electrode metal 2 is as follows:

(i) The heat-conductive core 8 is concentrically embedded in the electrode metal 2 by means of e.g. extrusion. The electrode metal 2 is machined to have the cone portion 6, the barrel portion 5 and the diameter-reduced neck 7 by means of plastic working or cutting procedure as shown in Fig. 2a. Upon applying the extrusion process, the front end 8a of the core 8 is located near the noble metal tip 4 within the range of 1.5 mm.

(ii) The noble metal tip 4 is formed into a disc-shaped configuration to measure 0.8 mm in diameter and 0.5 mm in thickness. Then, the noble metal tip 4 is concentrically located on the front end 3 of the electrode metal 2 as shown in Fig. 2b.

(iii) By using a YAG laser welder machine for example, laser beams (Lb) are applied to an interface between the noble metal tip 4 and the front end 3 of the electrode metal 2 all through their circumferential length while appropriately depressing the noble metal tip 4 against the front end 3 of the electrode metal 2 by means of a conical jig 10.

Thus, the laser welding procedure eventually forms the solidified alloy layer 9 at the interface to physically strongly bond the noble metal tip 4 to the front end 3 of the electrode metal 2 as shown in Fig. 2c.

In order to analyze how the wear- resistant property of the noble metal tip 4 is improved depending on the thermal conductivity (W/m•K) of the electrode metal 2, specimens A ~ H are prepared by changing constituents of the electrode metal 2 as shown in the following Table.

Table

	Cr (wt%)	Fe (wt%)	Si (wt%)	Hn (wt%)	Others (wt%)	Ni (wt%)	thermal conductivity (wt%)	trademark
specimenA	9	24	-	-	2	65	12W/m•K	Inconel 601
specimenB	8	16	-	-	-	76	15W/m•K	Inconel 600
specimenC	10	-	2	-	2	84	22W/m•K	
specimenD	10	-	-	-	-	90	25W/m•K	
specimenE	3	-	2	2	-	93	31W/m•K	
specimenF	1.5	-	1.5	2	-	95	35W/m•K	
specimenG	1	-	1	0.5	-	97.5	40W/m•K	
specimenH	-	-	-	-	-	100	85W/m•K	pure nickel

The specimens A ~ H are prepared and mounted on the spark plug, an endurance test is carried out with the spark plug installed on six-cylinder, 2000 cc internal combustion engine which is operated at 5500

rpm with full load for 400 hours. As shown in Fig. 3, it is found from the endurance test result how a spark gap (mm) increases depending wear of the noble metal tip 4. Fig. 4 shows a relationship between the thermal conductivity (W/m•K) of the electrode metal 2 and an increase of the spark gap (mm) caused by the wear of the noble metal tip 4.

Fig. 5 shows how the spark gap (mm) increases depending on a distance (L mm) between the noble metal tip 4 and the front end 8a of the heat-conductive core 8. In Fig. 5, the solid line curve represents the specimen E whose thermal conductivity (31 W/m•K) is greater than 30 W/m•K, while the broken line curve represents the specimen A whose thermal conductivity (12 W/m•K) is smaller than 30 W/m•K.

It is apparent from Fig. 3 that the increase of the spark gap (mm) is effectively controlled when the thermal conductivity is greater than 30 W/m•K as opposed to the case in which the thermal conductivity is smaller than 30 W/m•K.

It is also apparent from Fig. 4 that the thermal conductivity greater than 30 W/m•K rapidly drops the increase of the spark gap (mm).

As understood by Fig. 5, the increase of the spark gap (mm) is kept small until the distance (L) exceeds 1.5 mm when the thermal conductivity is greater than 30 W/m•K (specimen E) in opposition to the case in which the spark gap rapidly increases when the distance (L) exceeds 0.5 mm when the thermal conductivity is smaller than 30 W/m•K (specimen A). That is to say, the thermal conductivity greater than 30 W/m•K enables to avoid the rapid temperature rise of the noble metal tip 4 to minimize its wear substantially irrespective of the distance (L) between the heat-conductive core 8 and the noble metal tip 4.

Reverting to the prior art center electrode 100 in Fig. 6, the noble metal tip 103 is placed in the recess 102 which is provided on the front end of the electrode metal 101. This requires a step to make the recess 102 so as to increase the manufacturing cost.

When the diameter of the recess 102 is greater than that of the noble metal tip 103, the noble metal tip 103 is liable to tilt in the recess, thus making it difficult to stably bond the tip 103 to the front end of the electrode metal 101.

When the diameter of the recess 102 is smaller than that of the noble metal tip 103, it is difficult to place the tip 103 in the recess 102, thus taking a more time to bond the noble metal tip 103 to the electrode metal 101. This is particularly disadvantageous when reducing it to mass production.

On the other hand, with the present invention, the noble metal tip 4 is physically strongly welded to the electrode metal 2 by placing the noble metal tip 4 on the front end 3 of the electrode metal 2, and thus eliminating the above drawbacks to provide a long-lasting spark plug with low cost so as to keep sufficiently low temperature of the tip.

It is appreciated that the noble metal tip 4 may be welded to a ground electrode instead of the center electrode. In this instance, the ground electrode may have a heat-conductive core embedded in an electrode metal.

It is observed that the noble metal tip 4 may be secured to a side portion all or part of the electrode metal 2 instead of the front end 3 of the electrode metal 2.

It is also appreciated that the noble metal tip 4 may be secured to the front end 3 of the electrode metal 2 by means of electron beam welding or the like.

While the invention has been described with reference to the specific embodiments, it is understood that this description is not to be construed in a limiting sense in as much as various modifications and additions to the specific embodiments may be made by skilled artisan without departing from the scope of the invention.

Claims

1. A spark plug having an electrode including an electrode metal (2) of a heat-and erosion-resistant nickel alloy, a front end of the electrode having a noble metal tip (4) made or iridium or ruthenium and the electrode metal having a thermal conductivity of about 30 W/m.K or greater.

2. A spark plug according to claim 1, wherein the electrode metal (2) clads a heat-conductive core (8).

3. A spark plug according to claim 2, wherein a front end of the core (8) is in direct contact with the noble metal tip (4).

4. A spark plug according to claim 2, wherein a front end of the core (8) is located near the noble metal tip (4) within a range of about 1.5mm therefrom.

5. A spark plug according to any one of the preceding claims, wherein the noble metal tip (4) is laser welded to the front end of the electrode metal (2), thereby forming a solidified alloy layer (9) around the circumference of the interface between the noble metal tip (4) and the electrode metal (2).

Fig. 1

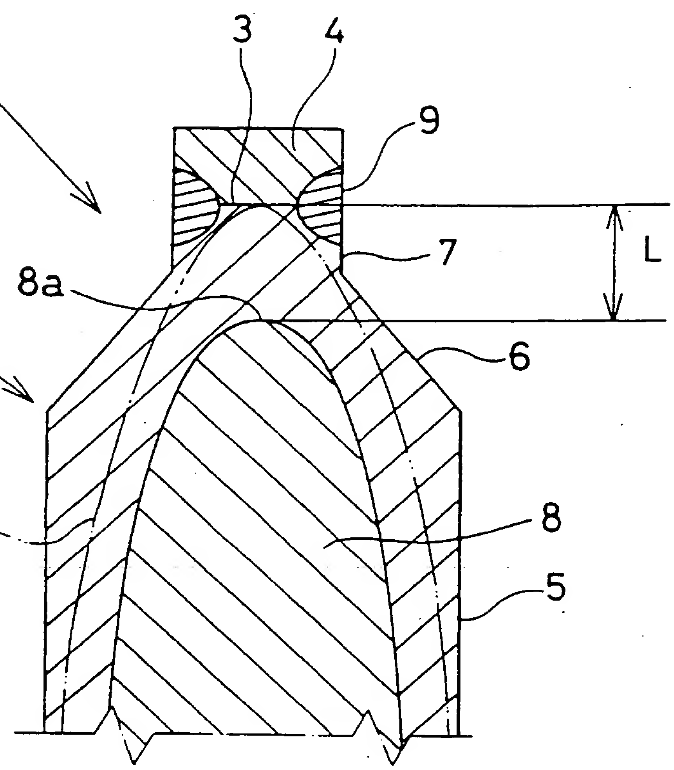


Fig. 2a

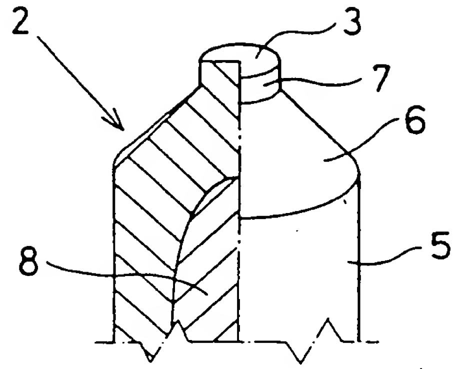


Fig. 2b

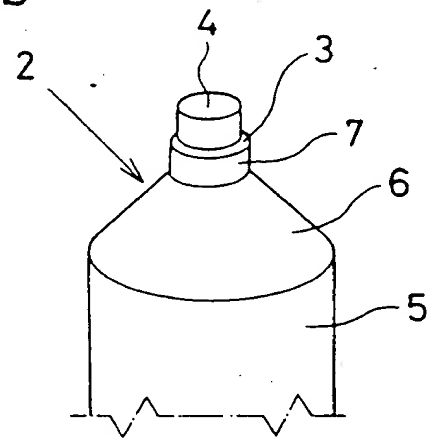


Fig. 2c

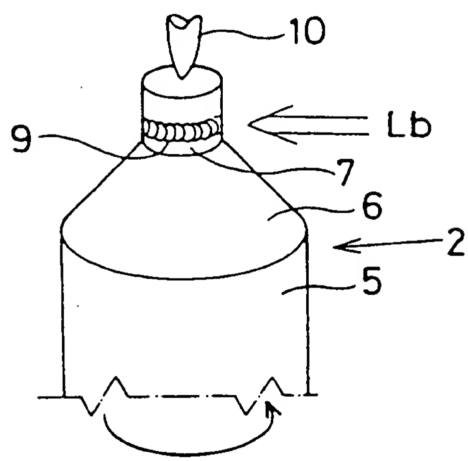


Fig. 3

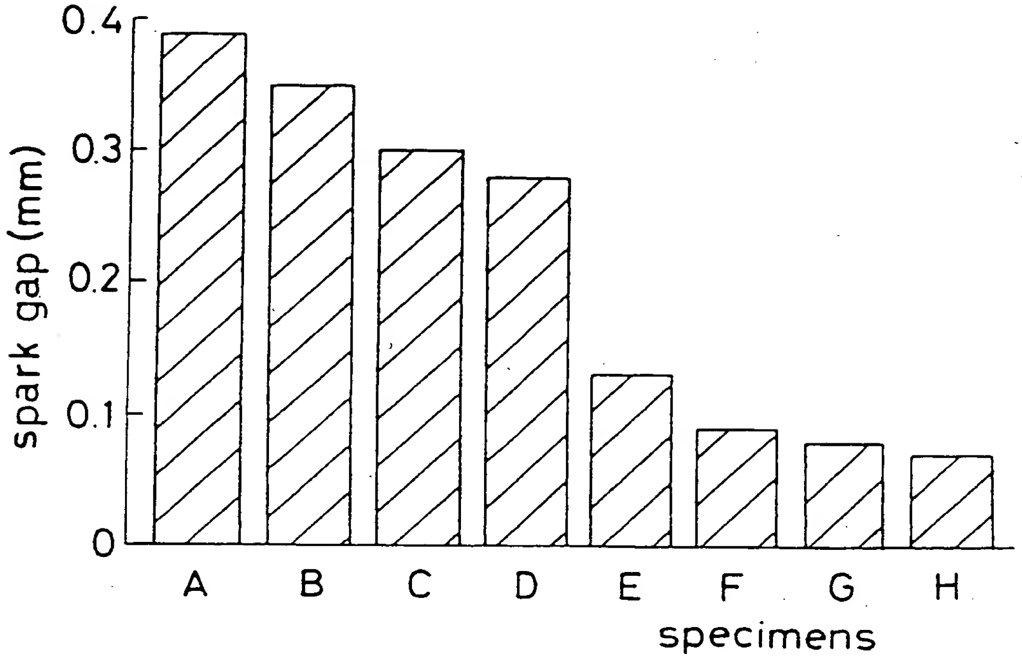

0.4
0.3
0.2
0.1
0
spark gap (mm)
A
B
C
D
E
F
G
H
specimens

Fig. 4

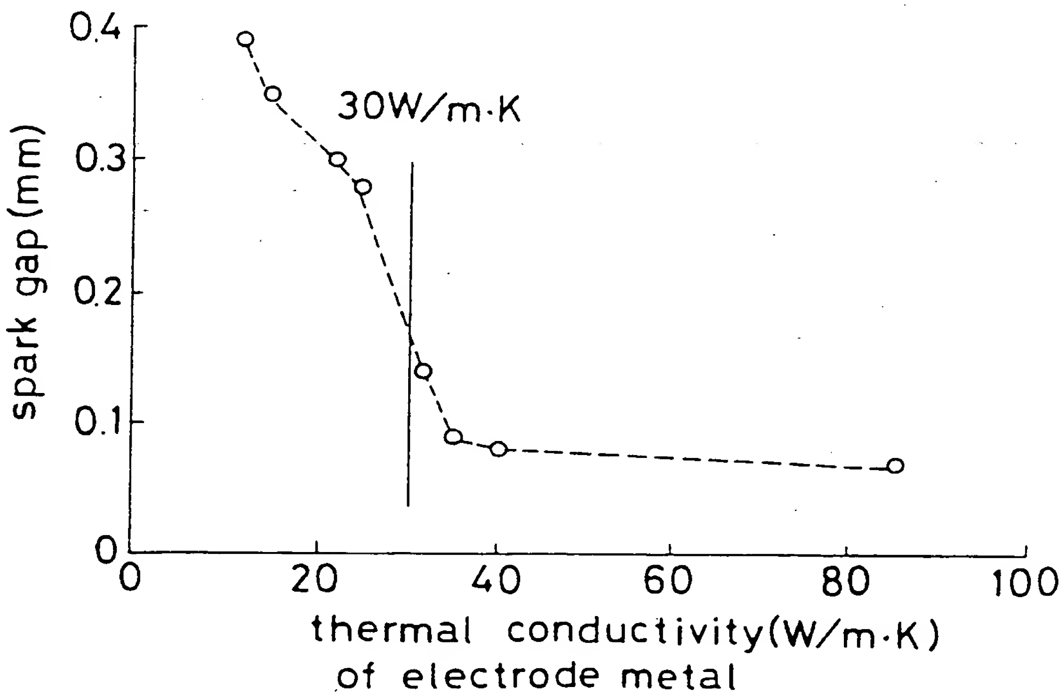

0.4
0.3
0.2
0.1
0
spark gap (mm)
30W/m·K
0
20
40
60
80
100
thermal conductivity(W/m·K)
of electrode metal

Fig. 5

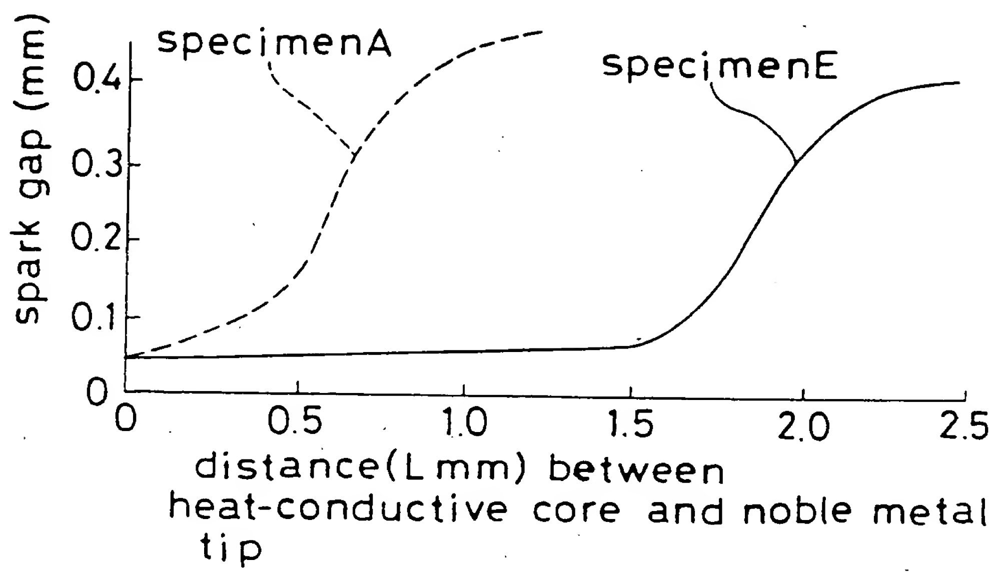
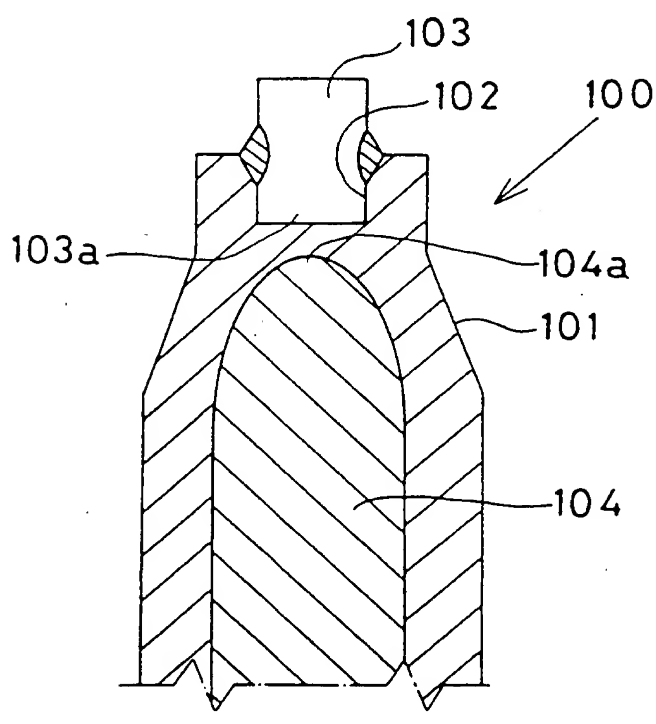


Fig. 6

Prior Art



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 4900

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 450 (E-1416) 18 August 1993 & JP-A-51 001 869 (NGK SPARK PLUG CIE) 23 April 1993 * abstract *	1 2,4	H01T13/39 H01T21/02
Y	PATENT ABSTRACTS OF JAPAN vol. 8, no. 71 (C-217) 3 April 1984 & JP-A-58 224 140 (TOKYO SHIBAURA DENKI K.K.) 26 December 1983 * abstract *	1	
A	EP-A-0 545 562 (NGK SPARK PLUG CIE) * column 5, line 9 - line 44; figure 1 *	1-3,5	
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 383 (E-1400) 19 July 1993 & JP-A-05 067 488 (NGK SPARK PLUG CIE) 19 March 1993 * abstract *		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A D,A	EP-A-0 537 031 (NGK SPARK PLUG CIE) & JP-A-4 350 (...)		H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 September 1994	Bijn, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document